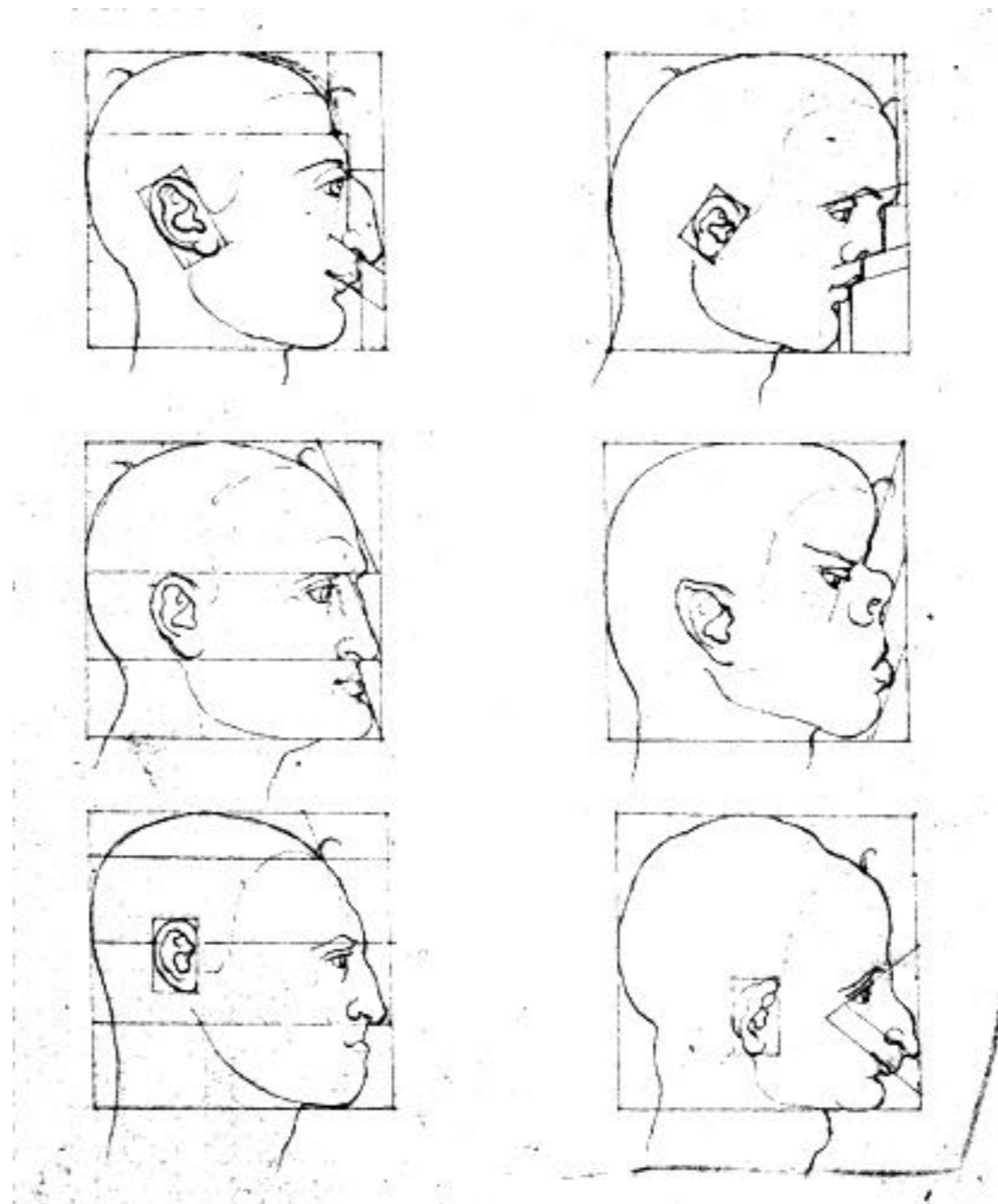


Facial attractiveness: a complexity look

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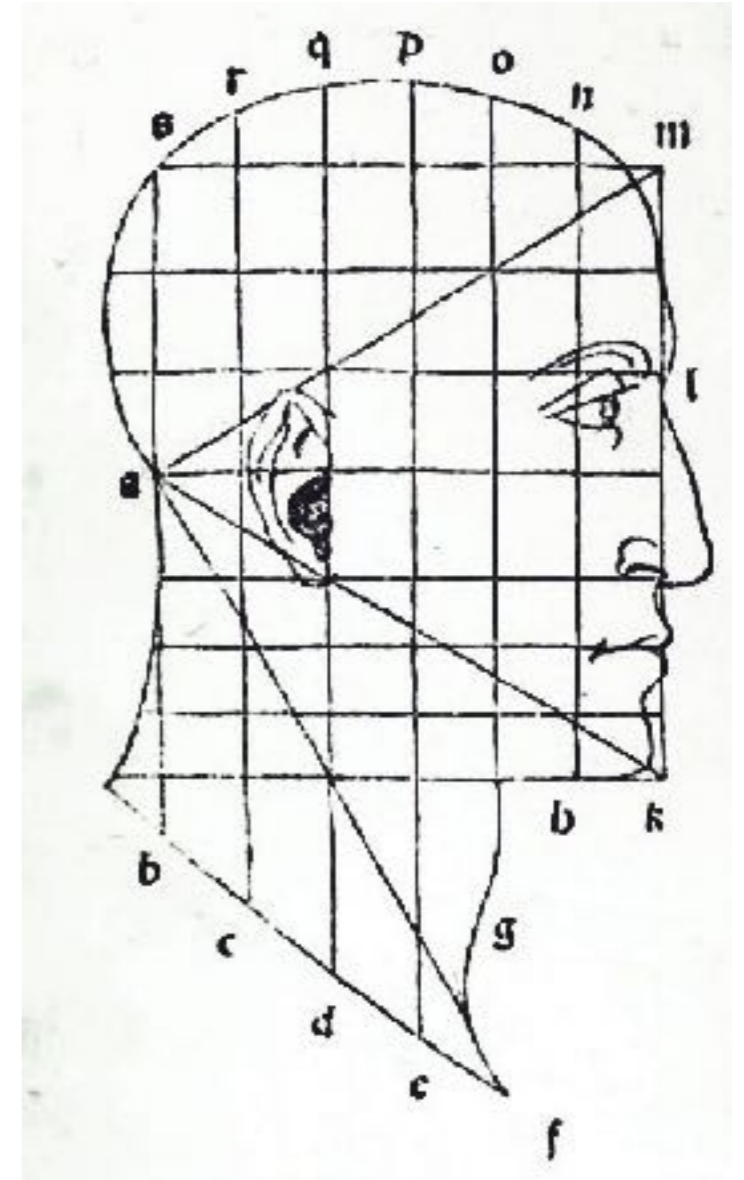


Questions on facial attractiveness

1. To what extent are our aesthetic criteria **universal** (dependence on the subject, on its sex, or cultural group)?
2. What are **the (most) relevant variables** [proportions/feature shapes]?
3. Can “beautiful faces” (for a subject) be characterised **as the maximum of some function** (or as the stationary state of some dynamics) in terms of such multi-dimensional variables?

Two ideas from the renaissance

- [Pacioli *De Divina Proportione* 1509]
About the ideal aesthetic proportions (among which the golden section).
- Horizontal inter-eye distance / face width



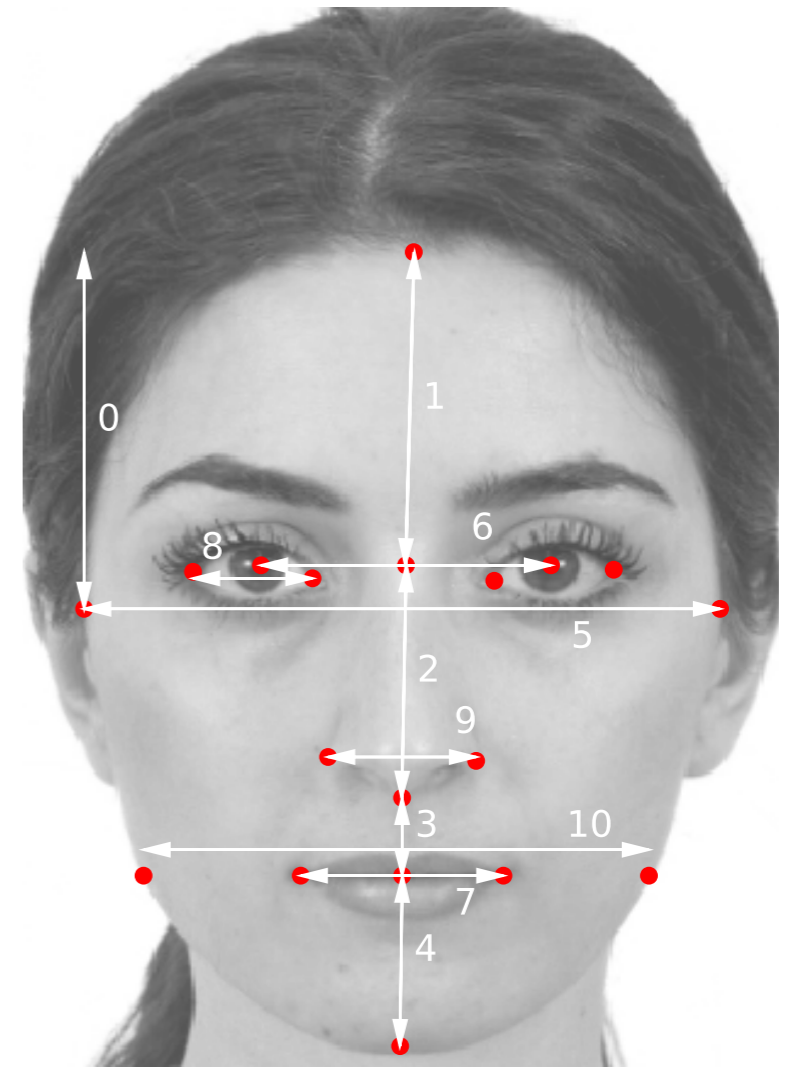
Da Vinci for *De Divina Proportione*

Facial attractiveness hypothesis

- **“Common sense hypothesis”** (beauty is in the eye of the beholder)
 - influenced by leaders, fashion, public media, personal preferences (self-similarity?)
- **Natural selection hypothesis** (beauty as a “health certificate”)
 - facial attractiveness judgements evolved as assessments of phenotypic condition
- **Sexual selection** [Darwin 1871]. Signal-receiving co-evolution of some (possibly handicap) traits, because attractive to the opposite sex (sexual vs. natural selection compromise).
 - Are they subjective, or have a biological basis? Do they signal fertility, or reproductive value? (refs. in [Johnston Franklin 1993])

A novel experimental scheme

- The faces are codified in a reduced number of dimensions (11), and **image deformation algorithms** are used to create an image from a vector $\vec{x} = (x_i)_{i=1}^{11}$ (and from a reference portrait)
- A genetic algorithm allows an experimental subject to sculpt his/her ideal \vec{x} (the voter playing the role of natural selection)





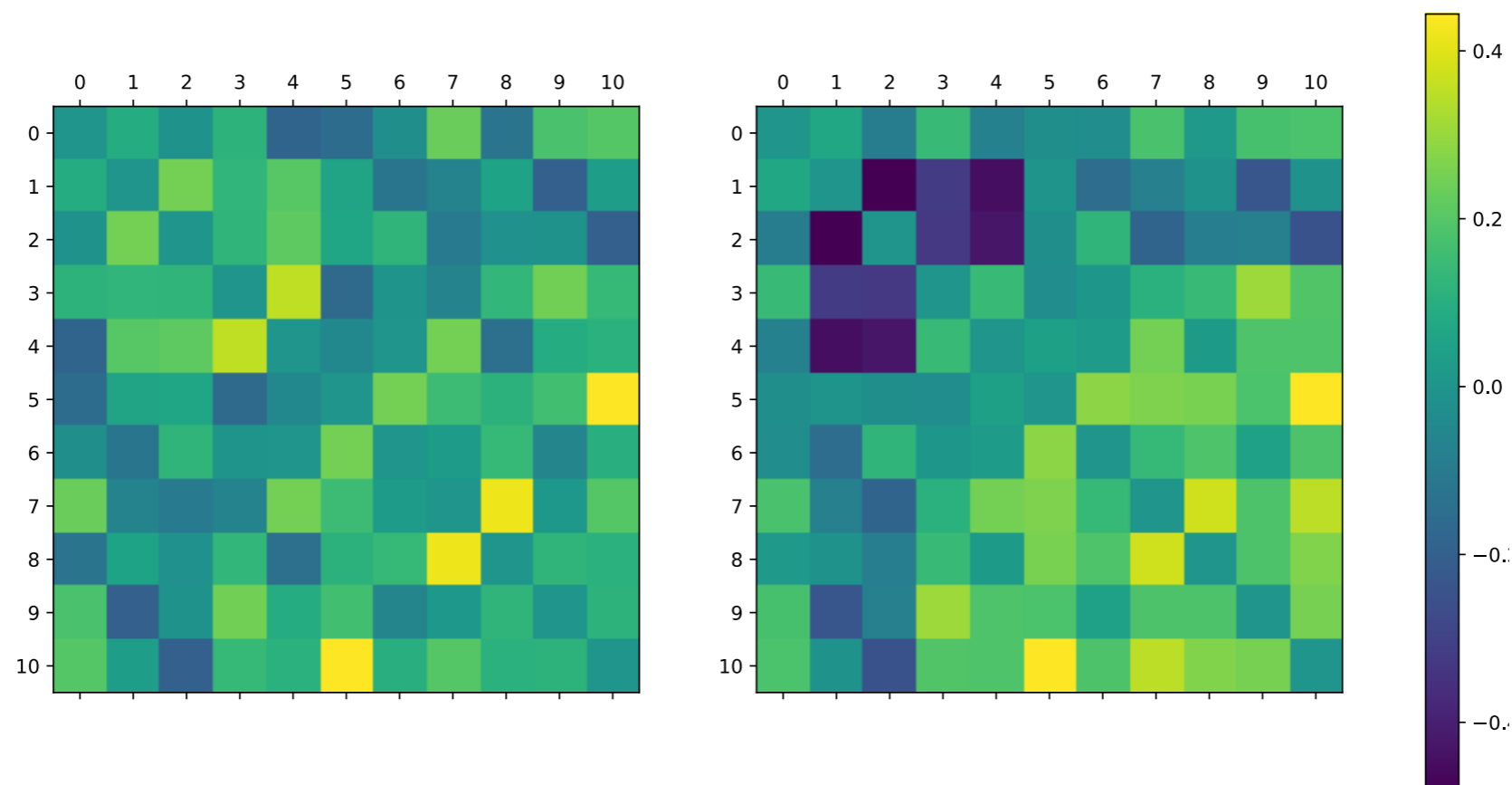
Results: [1] large variability



Results: [2] correlations and interactions

One can infer the *effective interaction* (in the subject's mind) between coordinates *via* **maximum entropy inference**

$$P(\vec{x}) = \frac{1}{Z} \exp \left[-\frac{1}{2} \sum_{i,j} J_{ij} x_i x_j \right]$$



Results: [2] correlations and interactions

Significant interaction terms, J_{ij} :

| | | | | |
|---|-----------|--------------------------------|--------------|--------------|
| - | hh | jaw w. -- face w. | -0.65 | -0.42 |
| - | hh | eye w. -- mouth w. | -0.51 | -0.27 |
| - | vv | chin h. -- nose-lips d. | -0.41 | -0.27 |
| - | vv | nose h. -- forehead h. | -0.29 | -0.21 |
| - | hh | inter-eye d. -- face w. | -0.29 | -0.08 |
| - | hv | mouth w. -- chin h. | -0.28 | -0.11 |
| | | . . . | | |
| + | hv | jaw w. -- nose h. | 0.23 | 0.10 |
| - | hv | inter-eye d. -- nose h. | -0.13 | -0.01 |
| + | hv | inter-eye d. -- forehead h. | 0.124 | 0.002 |

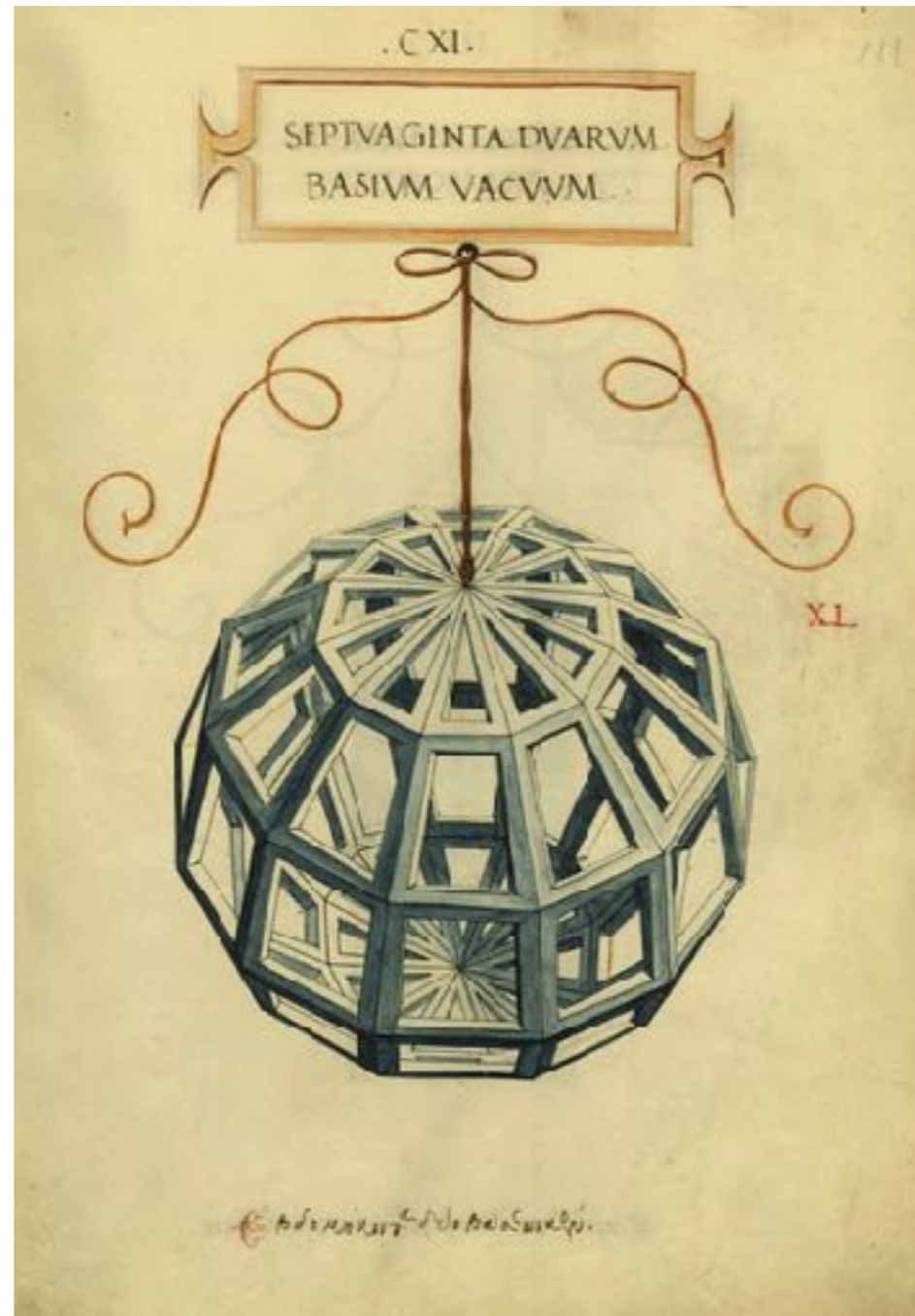
Ongoing work

- Assess the relevance of the variables not included in \vec{x} (i.e., the dependence on the reference portrait) (a problem of dimensionality reduction).



- Investigation of the influence of sex / age of the voter
- Of other selection criteria different from beauty

Thank you



Da Vinci for *De Divina Proportione*

Two ideas from ancient greek aesthetics

- “Crisippo stays that beauty does not reside on the single elements but on the mutual **proportions** between them, [...] as it is written on Polycleto's 'Canon'” [Galeno, *Placita Hippocratis et Platonis*, 2nd century]
- the optimal values of the proportions are given by the Polycleto's canon



Results: [2] correlations and interactions

Two-distance interactions are not enough to describe the experimental correlations

$$P(\vec{x}) = \frac{1}{Z} \exp \left[-\frac{1}{2} \sum_{i,j} J_{ij} x_i x_j + \frac{1}{6} \sum_{i,j,k} J_{ijk} x_i x_j x_k \right]$$

Significant THREE DISTANCE interaction terms, J_{ijk} :

| | | | | |
|---|-----|------------------------------------|--------|--------|
| + | vvv | chin h.--nose-lips d.--nose h. | 0.314 | 0.142 |
| - | hvv | inter-eye d.--chin h.--forehead h. | -0.326 | -0.143 |
| - | hvv | nose w.--chin h.--forehead h. | -0.292 | -0.132 |
| + | hvv | jaw w.--nose-lips d.--nose h. | 0.301 | 0.148 |

Against the “common sense” hypothesis

- Consensus across ethnic groups and sexual orientations [Cunningham et al 2005, Jones 1996]
- The same preferences exhibited by newborns [Langlois et al 1987], [Slater et al 1998], regardless of age, sex and race of the faces.
- [Chen et al 1997] “Owner vs. observer hypothesis”. Perception of beauty is less dependent on perceptual process of the observer (and more on the physiognomy of the owner) than perception of resemblance.

The “health certificate hypothesis”

- [Symons 1979], more generally: beauty as a sign of good phenotypic condition (GPC)
- No strong correlation between beauty and health observed (refs. in [Thornill Gangestad 1999]) (stronger in Environments of Evolutionary Adaptedness [Hill Hurtado 1996])
- Adaptationist approach: beauty as a GPC certificate reflects in a correlation between facial attractiveness and: facial **symmetry**, **averageness** and **sexually dimorphic features**

Facial symmetry

- Reason: asymmetry is known to generally reflect maladaptation (mutations, pathogens, toxins) (refs. in [Thornhill Gangestad 1999]).
- Evidences: with images of identical twins [Mealey et al 1999]; with artificially symmetrized faces [Perret et al 1999] [Rhodes et al 1998]; and with corrected double blemishes artefact [Swaddle Churthill 1995]
- [Sheib et al 1999]: symmetry may be associated with attractiveness because of other features co-varying with it. <<[...] the direct impact of symmetry [...] is not currently known, but it could be small>> [Thornhill Gangestad 1999].

Facial averageness

- Reason: averageness signals good performance in biological tasks [Symons 1979].
- Averaged *composites* of human faces are more attractive than the original faces [Grammer Thornhill 1994] [Langlois et al 1994] [O'Toole et al 1994]. (self-similarity clue [Penton-Voak Perret 1999])
- But the reason may be that it correlates with skin texture and symmetry [Alley Cunningham 1991]
- Moreover, the average can be improved with *composites of beautiful* people [Perret et al 1994]
- Sexually dimorphic traits (out-of-the average) are preferred [Perret et al 1998] [Thornhill Gangestad 1999] [Johnston Franklin 1993]



[\[pmsol3.wordpress.com\]](http://pmsol3.wordpress.com)

[Pallet et al 2010]

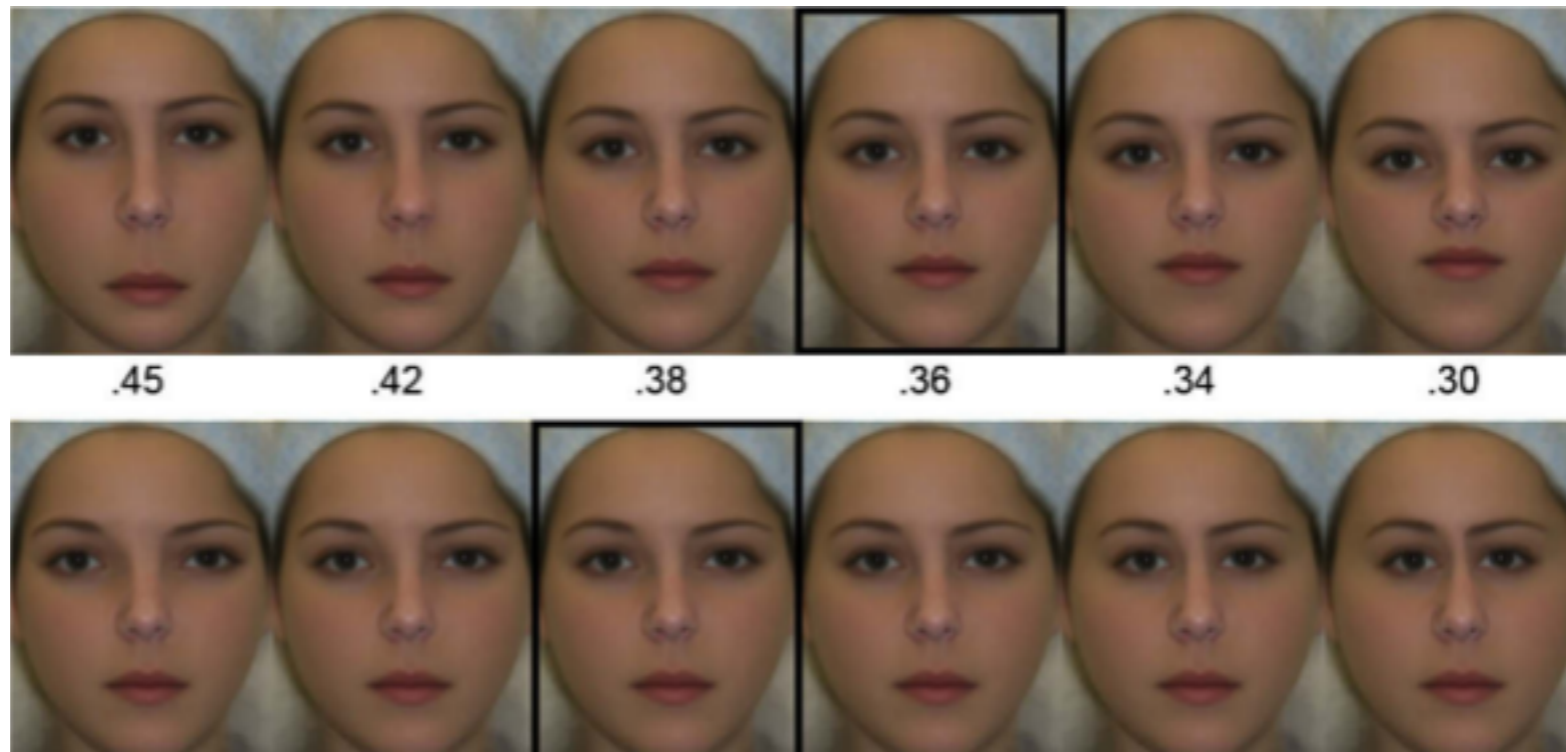
New “golden” ratios for facial beauty

Pamela M. Pallett^{a,*}, Stephen Link^a, Kang Lee^{a,b,*}

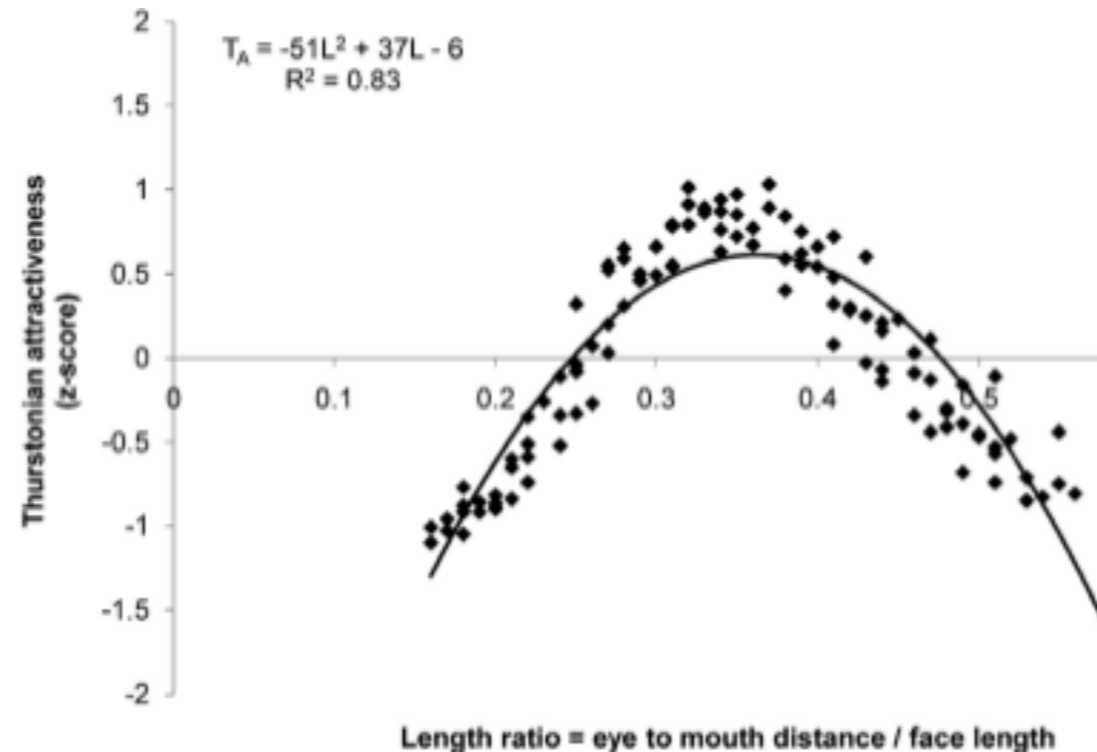
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- A set of faces is modified by changing the inter-eye (IED) and the eye-mouth (EM) distances, maintaining the features, and is scored by 32 voters.



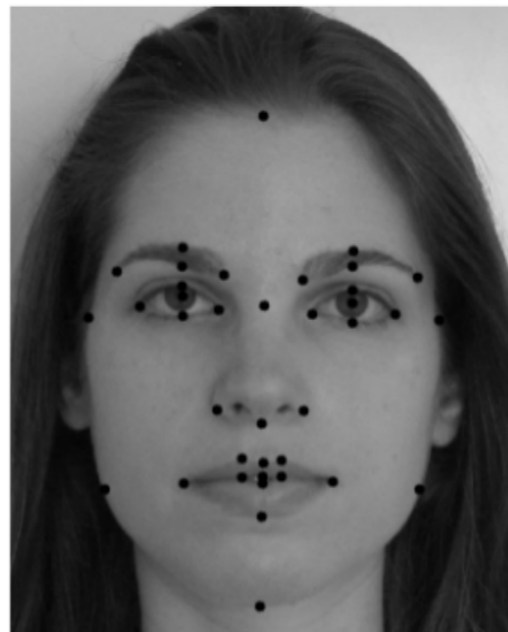
[Pallet et al 2010]



- IED/(face width) \sim 0.46, EM/(face height) \sim 0.36 (the golden ratio corresponds to \sim 0.38)
- These values correspond to the average face: the results support the average hypothesis (and the universality of proportions)
- Are (vertical-horizontal) correlations important?

[Eisenthal et al 2006]

- Machine learning analysis: faces are dimension-reduced using 1) a vector of landmark positions and 2) a PCA analysis (eigenfaces)



the landmarks used for feature-b

- Using the ratings of 28 voters, the beauty is estimated with the KNN algorithm, from the distances between faces in the reduced space.

[Eisenthal et al 2006]

- The trained predictor achieves a significant correlation with human ratings: “beauty is objective, and learnable by a machine”
- The vector representation (1) is more effective (confirmed by [Gunes Piccardi 2006])
- The PCA eigenvectors correlated with beauty are not the one with highest eigenvalue



Figure 4: Eigenfaces pertaining to highest eigenvalues (top row) and highest correlations with ratings (bottom row)

Questions on facial attractiveness

1. What are the relevant variables [proportions/facial feature shapes]?
2. Can the most beautiful faces can be characterised as the maximum of some function?
3. In this case, are there several 'maxima' (or saddle points)?
4. What are their essential properties? Are correlations important?
5. To what extent are the properties universal?

An experimental scheme proposal

- *A priori* dimensionality reduction: 11 distances (5 vertical, 6 horizontal). Fixed facial features (within the experiment).
- A genetic algorithm: a population of N faces.
 - **{1}** the voter selects [one among two] the preferred faces (no rating); **{2}** the $N/2$ remaining ones reproduce; **{3}** goto **{1}**.

Differential Evolution Genetic Algorithm (DEA)

N agents with D components, $v_n^{(d)}$

$$\{1\} \quad u_n^{(d)} = v_{n_1}^{(d)} + \mu(v_{n_2}^{(d)} - v_{n_3}^{(d)})$$

$$\{2\} \quad u_n^{(d)} = u_{\pi(n)}^{(d)} \quad \text{with prob. } \rho$$

$$\{3\} \quad v_n^{(d)} \equiv u_n^{(d)} \quad \text{if} \quad f[\vec{u}_n] < f[\vec{v}_n]$$

- vertical distances
 - 0 from the beginning of the forehead to the widest point in the zygomatic bone (does not enter in the normalization)
 - 1 forehead-pupil
 - 2 pupil-bottom of the nose
 - 3 bottom of the nose-mouth (junction of lips)
 - 4 junction of lips-bottom of the chin
- horizontal distances
 - 5 h0 face width (widest distance btwn. zygomatic bones)
 - 6 h1 between pupils
 - 7 h2 mouth width
 - 8 h3 eye width
 - 9 h4 nose width
 - 10 h5 jaw width at a vertical distance corresponding to the mouth (junction of lips)

The normalisation is:

$$n = \sum_{i=1}^4 v_i$$

Sexually dimorphic features

- Reason: they reflect (handicapping) sex hormones (testosterone/estrogens) (immunocompetence and dominance/fertility). [Andersson 1994] [Symons 1979]
 - In women: small chin, full lips, high cheekbones, narrow nose
- Computer vision techniques to enhance sexual dimorphisms [Perret et al 1998] [Johnston Franklin 1993]
- Further research analysed the emotional response to feminized facial features (see refs. in [Thornhill Gangestad 1999])
- Morphometrics techniques: attractiveness is correlated but not given by femininity [Valenzano et al 2006]

[Johnston Franklin 1993]

- A genetic algorithm allowing to change facial features and proportions. The attractiveness is evaluated in a 1-10 scale.



FIGURE 2. The user interface for the GA program showing the beauty rating scale and the controls for moving or freezing features.

[Johnston Franklin 1993]

- Systematic departure from the average face, supporting sexual selection hypothesis



FIGURE 5. The highest rated facial composite (left) and a composite having the same features but in the proportions of the average face in the population (right).

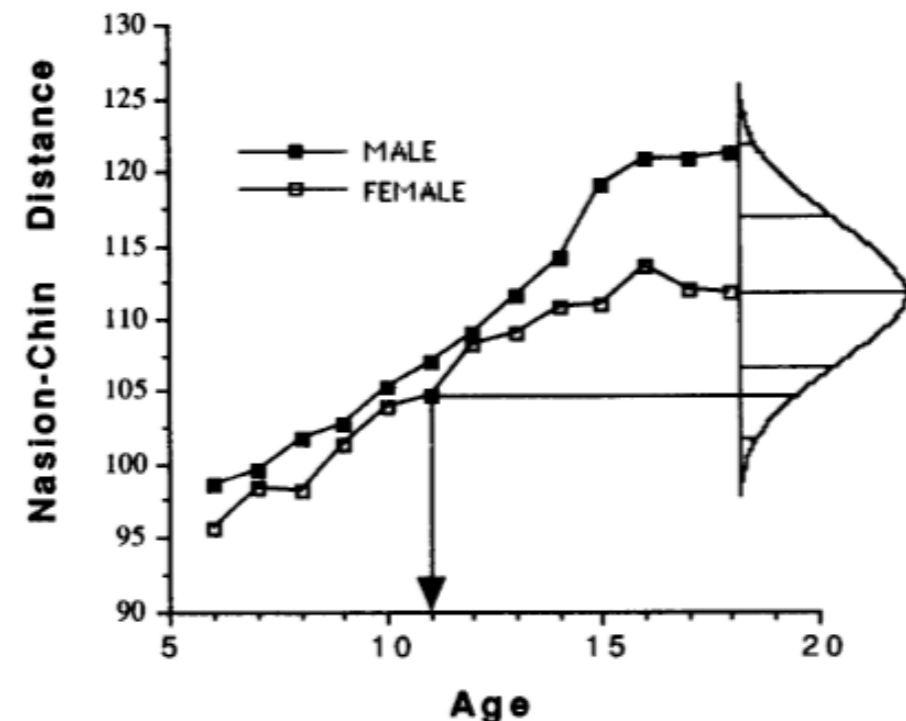
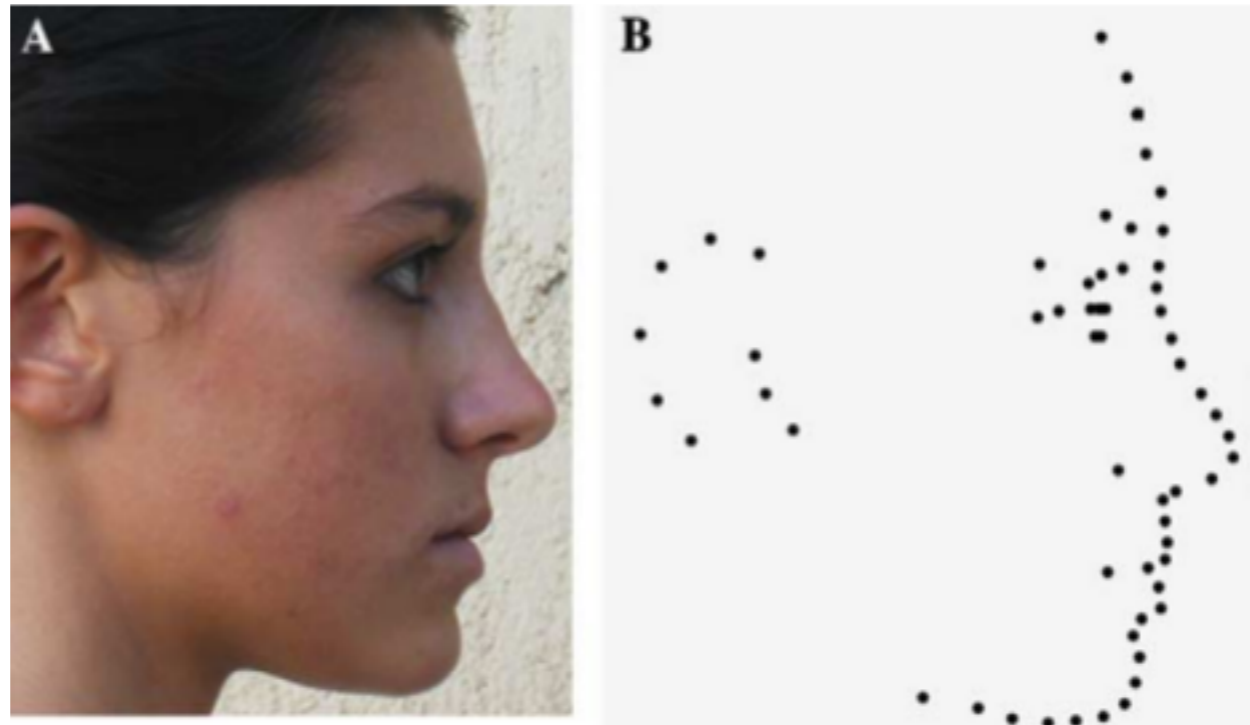


FIGURE 4. The growth of the Nasion-Chin distance in males and females (6 to 18 years) according to Farkas (1981). The highest rated beautiful composite is between one and two standard deviations smaller than the mean for 18 year old females and corresponds to the mean size found in 11 year old females (arrow).

- The preferred face age is estimated as 24.9, maximum fertility age
- Small nasion-chin distance of most rated faces is interpreted as a preference for low-androgen traits

[Valenzano et al 2006]

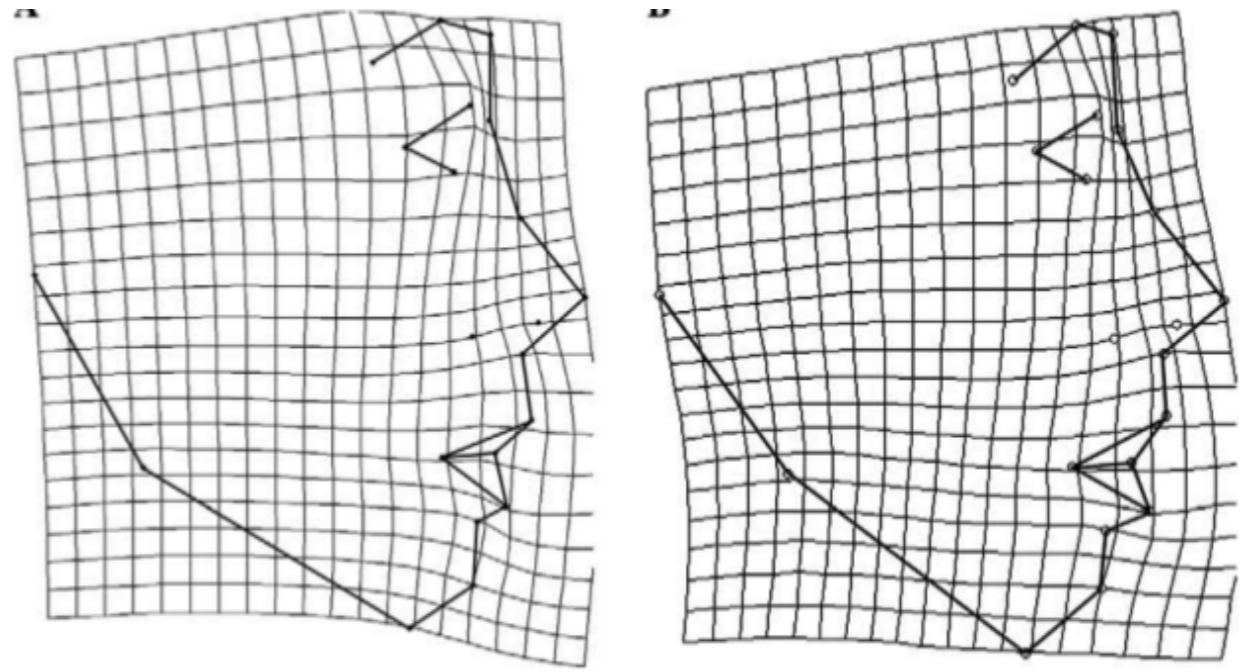
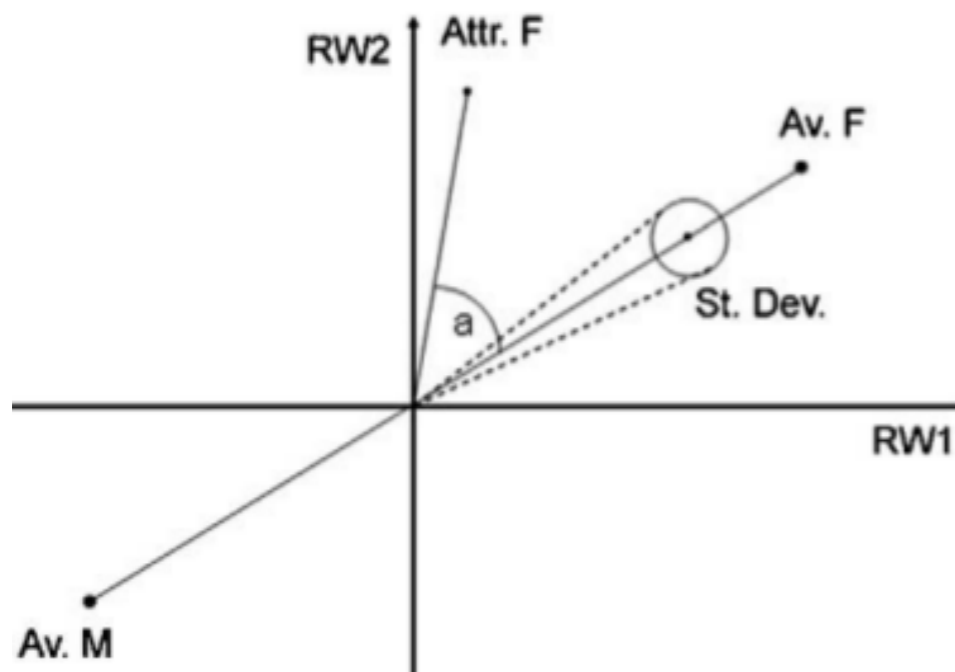
- Geometric Morphometrics: each face as a point in an Euclidean face space



- Scattered distances from the average landmark positions + spline fit + eigenfunction decomposition (the coefficients each are an Euclidean base)

[Valenzano et al 2006]

- The dimorphic axis is constructed as the (average male - average female) vectors. The attractive female face (from rates from 22 subjects) is seen to not being parallel to the dimorphic axis.



- The differences between both are seen to be more prominent in the lower part of the face.

'Tis not a lip, or eye, we beauty call,
But the joint force and full result of all.
Thus when we view some well-proportion'd dome,
(The world's just wonder, and ev'n thine, O Rome!)
No single parts unequally surprise;
All comes united to th' admiring eyes;
No monstrous height, or breadth, or length appear;
The whole at once is bold, and regular.

[Pope *An essay on Criticism* (1711)]

BERGANZA-Y un día que, entre dos luces, iba yo diligente a llevarle la porción, oí que me llamaban por mi nombre desde una ventana; alcé los ojos y vi una moza hermosa en extremo [...]. Lleguéme a ella, como si fuera a ver lo que me quería, que no fue otra cosa que quitarme lo que llevaba en la cesta [...]. Bien pudiera yo volver a quitar lo que me quitó, pero no quise, por no poner mi boca jifera y sucia en aquellas manos limpias y blancas.

CIPIÓN-Hiciste muy bien, por ser prerrogativa de la hermosura que siempre se le tenga respecto.

[Cervantes, Novelas ejemplares ~1613]